

SURVIVAL AND GROWTH OF MATCHED PLANTINGS  
OF LAKE TROUT (*SALVELINUS NAMAYCUSH*), BROOK TROUT  
(*SALVELINUS FONTINALIS*), AND LAKE X BROOK F<sub>1</sub>  
SPLAKE HYBRIDS AND BACKCROSSES  
IN NORTHEASTERN ONTARIO LAKES

Peter E. Ihssen

Michael J. Powell

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1982  
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Ministry of  
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Hon. Allan W. Pope  
Minister

W. T. Foster  
Deputy Minister

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## ABSTRACT

Ihssen, P. E., M. J. Powell, and M. Miller. 1982. Survival and Growth of Matched Plantings of Lake Trout (*Salvelinus namaycush*), Brook Trout (*Salvelinus fontinalis*), and Lake x Brook F<sub>1</sub> Splake Hybrids and Backcrosses in Northeastern Ontario Lakes. Ont. Fish. Tech. Rep. Ser. No. 6: iii & 12 p.

Matched plantings of lake trout (*Salvelinus namaycush*), F<sub>1</sub> splake hybrids and lake trout backcrosses, and brook trout (*Salvelinus fontinalis*), F<sub>1</sub> splake hybrids and brook trout backcrosses were made annually in four small northeastern Ontario lakes for three successive years. The relative performance of the three different crosses in each lake was assessed by gillnetting in the fall, for seven successive years. F<sub>1</sub> hybrids were recovered at rates two to three times greater than the backcrosses, brook trout or lake trout, from all lakes, except one, where only one lake trout to 346 F<sub>1</sub> hybrids was recovered. The number of kg recovered per kg planted ranged from 2.5 to 4.4 for the F<sub>1</sub> hybrids, 0.3 to 1.3 for the backcrosses, and 0.0 to 1.0 for the brook trout and lake trout. The first planting gave the best returns, both in terms of numbers and kilograms recovered; the middle plant, the poorest. The growth rates, recoveries, and condition factors were correlated among crosses, lakes and plantings. The plantings, crosses, or lakes that gave the highest returns also gave the fastest growth rates and the largest condition factors. The F<sub>1</sub> hybrids from the two lakes that gave the fastest growth and highest rates of return matured significantly earlier in life (50% mature at about age 2.5 to 3.0, sexes combined) than those from the two lakes with the slower growth and lower returns (age 3 to 3.5).

Keywords: matched plantings, survival, growth, maturation, hybrids, *Salvelinus namaycush*, *Salvelinus fontinalis*.

SURVIVAL AND GROWTH OF MATCHED PLANTINGS  
OF LAKE TROUT (*Salvelinus namaycush*), BROOK TROUT  
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SPLAKE HYBRIDS AND BACKCROSSES

IN NORTHEASTERN ONTARIO LAKES

INTRODUCTION

Traditionally, management of sport fisheries for brook trout (*Salvelinus fontinalis*) and lake trout (*S. namaycush*), in northern Ontario lakes, has been based almost exclusively on put-delay-take of cultured yearlings. Survival and growth of hatchery reared trout in these lakes have been generally poor and inadequate to meet management objectives.

A cooperative research program, by the Fisheries Research Section and the Northeastern Region of the Ontario Ministry of Natural Resources, was initiated in 1972 to study the potential of lake trout x brook trout (splake) hybrids for improved angling opportunities, in lakes in which indigenous trout species provide only marginal or insignificant fisheries. Various strains of splake were evaluated for survival and growth in lakes with limnological characteristics between those considered ideal for lake trout and brook trout.

Comparisons of the relative growth and survival of brook trout and F<sub>1</sub> splake hybrids have been made previously (Fraser 1972, 1980). These studies have shown that F<sub>1</sub> hybrids give superior performance over brook trout, especially in terms of survival. The relative performance of lake trout, lake trout backcrosses, and F<sub>1</sub> hybrids in Lake Huron has been studied by Spangler and Berst (1976). They found that F<sub>1</sub> hybrids and backcrosses had similar growth rates, with lake trout being slower in growth. The study did not compare relative survival of the three crosses. The present study was designed to compare the relative growth and survival of brook trout, F<sub>1</sub> splake, and brook trout backcrosses in lakes that are normally man-

aged for brook trout put-delay-take; and lake trout, F<sub>1</sub> splake and lake trout backcrosses in lakes normally managed for lake trout put-delay-take.

MATERIALS AND METHODS

Four lakes on the Precambrian Shield in the Espanola and Blind River districts of northeastern Ontario were chosen for this study (Table 1). Existing fish populations included white suckers (*Catostomus commersoni*) and minnows (Cyprinids) in all four lakes, lake herring (*Coregonus artedii*) in Pleasant Lake, and one year class of planted lake trout (1972 fall fingerlings) in Bobowash Lake. Bobowash Lake and Lake 97 are typical of lakes which support angling fisheries sustained by periodic plantings of yearling lake trout. These two lakes were planted with equal numbers of marked (fin clipped) yearling F<sub>1</sub> splake, lake trout, and lake trout backcrosses in May of 1974, 1975 and 1976 (Table 2). Pleasant Lake and Lake 78 are typical of those lakes which support put-take fisheries of brook trout. Each of these two lakes was planted with equal numbers of marked yearling F<sub>1</sub> splake, brook trout, and brook trout backcrosses in May of 1974, 1975 and 1976 (Table 2). Pleasant Lake was accessible by road; the other three lakes, only by air. All lakes were hand planted, either from trucks or from the planes, after landing. Bobowash Lake, Lake 97, and Lake 78 were planted at the rate of 74 fish per ha; Pleasant Lake, because of its small size, was planted at the rate of 190 fish per ha. An attempt was made to rear and select fish of the same size for each cross planted. This was not entirely successful because of differences in growth rate among the crosses under hatchery conditions (Table 2). The fin clips were rotated among the three crosses in each lake to eliminate any possible bias due to different fins clipped, and also to make identification of the same cross, planted in different years, easily possible. All lakes were closed to angling for the duration of the experiment.

Assessment was carried out in the fall of each year from 1974 to 1980, inclusive, for the lake trout type lakes, and from 1974 to 1979, inclusive, for the brook trout type lakes. Overnight sets of experimental gangs of gill nets

Table 1. Description of study lakes.

| Name of Lake  | Latitude | Longitude | Area<br>(ha) | Max.<br>depth<br>(m) | Mean<br>depth<br>(m) | pH  | Total<br>Alkalinity | TDS |
|---------------|----------|-----------|--------------|----------------------|----------------------|-----|---------------------|-----|
| Lake 97       | 46°53'N  | 82°07'W   | 94.8         | 20.7                 | 4.9                  | 5.5 | -0.24               | 18  |
| Lake 78       | 46°49'N  | 82°08'W   | 81.1         | 18.3                 | 6.6                  | 6.2 | 2.25                | 19  |
| Bobowash Lake | 46°34'N  | 82°47'W   | 63.9         | 42.7                 | 10.1                 | 6.2 | 3.38                | 13  |
| Pleasant Lake | 46°13'N  | 81°39'W   | 15.2         | 9.4                  | 5.4                  | 6.8 | 4.43                | 15  |

Table 2. Planting data for the matched planting experiment, northeastern Ontario lakes.

| Year of plant | Cross <sup>a</sup> | Mean total length (mm) | Mean weight (g) | Lake trout type lakes |                     |         | Brook trout type lakes |                     |         |
|---------------|--------------------|------------------------|-----------------|-----------------------|---------------------|---------|------------------------|---------------------|---------|
|               |                    |                        |                 | Clip <sup>b</sup>     | No. of fish planted |         | Clip <sup>b</sup>      | No. of fish planted |         |
|               |                    |                        |                 |                       | Bobowash Lake       | Lake 97 |                        | Pleasant Lake       | Lake 78 |
| 1974          | LT                 | 104.1                  | 7.3             | LV                    | 1550                | 2300    |                        |                     |         |
|               | LTBC               | 116.8                  | 13.7            | RP                    | 1550                | 2300    |                        |                     |         |
|               | F <sub>1</sub>     | 104.1                  | 9.6             | AD                    | 1550                | 2300    | AD                     | 900                 | 2000    |
|               | BTBC               | 142.2                  | 30.3            |                       |                     |         | LP                     | 900                 | 2000    |
|               | BT                 | 147.3                  | 29.8            |                       |                     |         | LV                     | 900                 | 2000    |
| 1975          | LT                 | 101.6                  | 5.7             | RV                    | 1550                | 2300    |                        |                     |         |
|               | LTBC               | 119.4                  | 13.2            | LP                    | 1550                | 2300    |                        |                     |         |
|               | F <sub>1</sub>     | 127.0                  | 16.3            | AD,RV                 | 1550                | 2300    | AD,RV                  | 900                 | 2000    |
|               | BTBC               | 152.0                  | 37.8            |                       |                     |         | RP                     | 900                 | 2000    |
|               | BT                 | 157.4                  | 36.3            |                       |                     |         | RV                     | 900                 | 2000    |
| 1976          | LT                 | 104.0                  | 9.3             | AD,LV                 | 1550                | 2300    |                        |                     |         |
|               | LTBC               | 116.0                  | 14.9            | AD,LP                 | 1550                | 2300    |                        |                     |         |
|               | F <sub>1</sub>     | 115.0                  | 16.1            | AD,RP                 | 1550                | 2300    | AD,RP                  | 900                 | 2000    |
|               | BTBC               | 144.0                  | 33.1            |                       |                     |         | RP                     | 900                 | 2000    |
|               | BT                 | 149.0                  | 36.6            |                       |                     |         | AD,LV                  | 900                 | 2000    |

<sup>a</sup> LT = Lake Manitou lake trout female x male; LTBC = Lake Manitou lake trout female x Tarentorus Hatchery F<sub>4.5</sub> splake male; F<sub>1</sub> = Lake Manitou lake trout female x Nestor Lake brook trout male; BTBC = Tarentorus Hatchery F<sub>4.5</sub> splake female x Nestor Lake brook trout male; BT = Hill's Lake Hatchery brook trout female x male.

<sup>b</sup> AD = Adipose clip; RP = right pectoral clip; LP = left pectoral clip; LV = left ventral clip; RV = right ventral clip.

were used. Each experimental net was 135 m long, consisting of 15-metre sections ranging in mesh size from 20 mm to 127 mm stretched measure. Bottom sets were used exclusively and an attempt was made to sample every major basin or bay in shallow and deep water. The objective was to apply sufficient netting effort to sample approximately 100 of the planted fish from each lake, annually. This usually required from 1830 m to 3660 m of netting effort, or from 37 m to 148 m per hectare. Weight, fork length, total length, state of maturity, and stomach contents data were taken for each fish, immediately after capture.

In this report, the abbreviations BT, LT, BTBC, LTBC, and F<sub>1</sub> will be used to denote brook trout, lake trout, brook trout backcrosses, lake trout backcrosses, and F<sub>1</sub> hybrids, respectively. The F<sub>1</sub> hybrids were produced by crossing lake trout females with brook trout males. The brook trout and lake trout backcrosses were produced by crossing F<sub>4.5</sub> splake females with brook trout males, and lake trout females with F<sub>4.5</sub> splake males, respectively (Table 2). F<sub>4.5</sub> splake hybrids are defined as the progeny from crosses between F<sub>3</sub> and F<sub>4</sub> hybrids.

## RESULTS

### CATCH PER UNIT EFFORT (CUE)

CUE calculations are used here to give a rough comparison of the productivity among the four lakes. The experiment was not designed to make accurate comparisons of this type, but rather, to provide information on the relative performance of the different crosses within each lake. Effort varied somewhat from year to year for each lake, both in terms of the amount of netting used and the location of nets within lakes, in order to obtain sufficient samples from each lake for comparisons among the matched plantings within each lake.

Comparing the returns from the two brook trout type lakes (Table 3), it is seen that Lake 78 gave much higher returns than Pleasant Lake. The lake herring population of Pleasant Lake may be competing with the trout, especially the smaller trout. The two lake trout type lakes gave similar returns, with Lake 97 slightly better than Bobowash. Bobowash was the only lake that con-

Table 3. Catch per unit effort in kg/1000 m of gill net per day.

| Lakes       | Year of Capture          |             |             |             |             |             |                   |
|-------------|--------------------------|-------------|-------------|-------------|-------------|-------------|-------------------|
|             | 1974                     | 1975        | 1976        | 1977        | 1978        | 1979        | 1980 <sup>b</sup> |
| LT Type:    |                          |             |             |             |             |             |                   |
| Bobowash L. | 6.9 (11.2 <sup>a</sup> ) | 11.4 (14.0) | 26.1 (36.3) | 58.1 (81.8) | 35.1 (62.8) | 30.5 (52.8) | 31.3 (41.2)       |
| Lake 97     | 1.5                      | 15.7        | 62.6        | 60.5        | 61.0        | 39.7        | 16.2              |
| BT Type:    |                          |             |             |             |             |             |                   |
| Pleasant L. | 1.7                      | 9.3         | 17.7        | 12.0        | 21.4        | 16.8        | -                 |
| Lake 78     | 16.5                     | 30.6        | 54.9        | 75.7        | 47.5        | 13.4        | -                 |

<sup>a</sup> Includes lake trout from a 1973 planting.

<sup>b</sup> BT type lakes were not sampled in 1980.

tained lake trout from a previous 1972 planting.

The LT type lakes sustained higher catches longer after the last planting than the BT type lakes (Table 3). This was the result of LTBC and LT (in Bobowash Lake) surviving longer after the last planting than BTBC or BT. BT practically disappeared from the catch one year after the last planting, and BTBC contributed only a small percentage to the catch.

#### COMPARATIVE RECOVERIES WITHIN LAKES

From 44,550 fish planted, 1772 (about 4%) were recovered. The total weight planted was 1121 kg; the total weight recovered was 1303 kg. Of the 1772 fish recovered, 1158 (65%) were F<sub>1</sub> hybrids, 263 (15%) were LTBC, 154 (9%) were BTBC, 142 (8%) were BT, and 45 (3%) were LT.

The relative recoveries within each lake are directly comparable because the crosses were exposed to the same netting effort. F<sub>1</sub> hybrids were recovered from both types of lakes about three times more frequently than backcrosses (Table 4). The recovery ratio of F<sub>1</sub>'s to LT was 6.5 to 1 and 346 to 1, for Lakes Bobowash and 97, respectively. Brook trout did somewhat better, in terms of numbers recovered, with a ratio of F<sub>1</sub>'s to BT of 3 to 1 and 4 to 1, for Pleasant Lake and Lake 78, respectively. BT contributed only a small proportion to the catch, however, after age three (Fig. 1). LTBC, on the other hand, contributed significant proportions to the catch up to age 7; and LT, in Bobowash Lake, contributed an increasing proportion to the catch up to the oldest fish sampled (age 8), among which LT were predominant (Fig. 1). The absolute abundance of 8 year old lake trout was very low, however, and they were found only in Bobowash Lake. No lake trout, other than one four year old, were recovered from Lake 97.

In terms of kg recovered per kg planted, the F<sub>1</sub>'s again outperformed the backcrosses and paren-

tal species (Table 4). Lake 78 gave the best returns for F<sub>1</sub>'s (4.4 kg/kg planted) relative to BTBC (0.3 kg/kg planted) and BT (0.2 kg/kg planted). These figures, of course, do not represent the total production from the plant, because the sampling program was intended to take only enough fish to make meaningful comparisons among the crosses. In terms of kg recovered per kg planted, BTBC did more poorly than LTBC because they were planted at a larger size and few were recovered after age three (Fig. 1). The same applies to BT versus LT, except for Lake 97, where only one LT was recovered. The LT from Bobowash Lake had slightly better returns than the LTBC, in terms of kg recovered/kg planted, even though about twice as many LTBC than LT were recovered. This is primarily because LT were planted at a smaller size than LTBC.

#### COMPARISON OF SUCCESSIVE PLANTINGS

The proportion of fish from the middle planting (1975), that contributed to the catch, was only marginal for the BT type lakes (Fig. 2). The number of 2 to 5 year olds recovered for the 1974, 1975, and 1976 planting was 449, 58, and 275, respectively. A similar pattern of poor return from the middle planting, and a somewhat reduced return from the third planting, as compared to the first, was observed for the LT type lakes. The number of 2 to 6 year old fish recovered from the 1974, 1975, and 1976 planting was 384, 189, and 323, respectively. The first planting contributed the largest proportion of the returns for Lake 78 and Bobowash Lake (Fig. 2). The third planting also gave very good returns for Pleasant Lake and Lake 97. It appears that the success of the first planting negatively affects the success of the subsequent plantings. The two lakes with the best success of the first planting (Lakes 78 and Bobowash), gave the poorest returns from the second planting (Fig. 2); whereas, Lake 97, which had the

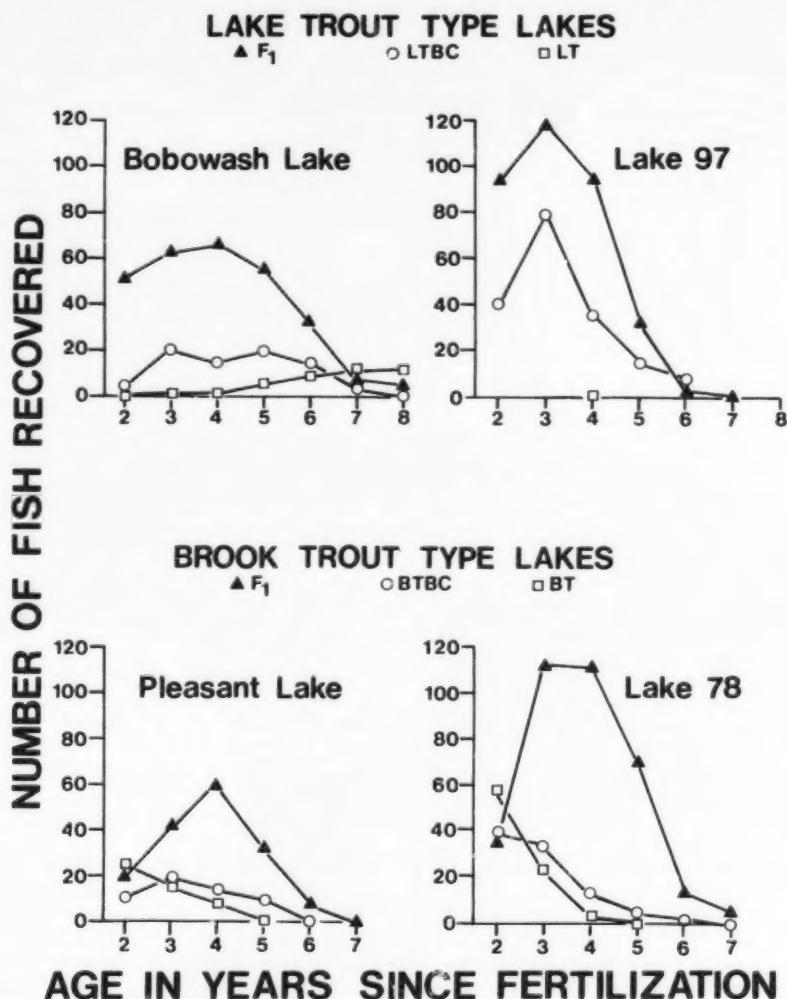


Figure 1. The number of fish recovered for each age class from the four experimental lakes. For the BT type lakes sampled up to 1979, the number of 6 and 7 year olds recovered is based on only 2 and 1 planting(s), respectively, compared to 3 plantings for the other age classes. Similarly, for the LT type lakes sampled up to 1980, the number of 7 and 8 year olds is based on only 2 and 1 planting(s), respectively, compared to 3 plantings for the other year classes.

poorest relative returns from the first planting, gave the best returns for the second planting.

#### FEEDING, GROWTH AND CONDITION

Only a cursory examination of stomach contents, by incidence of different food items, was carried out (Table 5). As expected, since the fish were sampled during the spawning season (late September, early November), a large proportion of the stomachs were empty. Crayfish were the most frequently encountered stomach remains. The incidence of crayfish is probably overestimated, because they are digested more slowly than most other food items, and they are also the most easily identified.

The  $F_1$ 's grew faster than all the other crosses, in all four lakes (Fig.3). BT and BTBC had similar growth rates. Since only a few LT were recovered, little can be said about their rate of growth, but it appears that they grow considerably more slowly than the  $F_1$ 's or LTBC, especially up to age six (Fig. 3).

The relative sizes of the crosses at planting bears little relation to the relative sizes of the crosses in later years. For example, the  $F_1$ 's were much smaller at planting than the BTBC or BT (Table 2), but after only 18 months in the wild (in Pleasant Lake and Lake 78) the  $F_1$ 's had outgrown both the BTBC and BT. Similarly, the relative sizes of the  $F_1$ 's and LTBC's reversed after planting in the LT type lakes.

Table 4. Recoveries from matched planting experiments.

|                | No. Planted | No. Recovered | % Recovered | kg Planted | kg Recovered | kg Recovered/<br>kg Planted |
|----------------|-------------|---------------|-------------|------------|--------------|-----------------------------|
| LT TYPE LAKES: |             |               |             |            |              |                             |
| Bobowash Lake  |             |               |             |            |              |                             |
| F <sub>1</sub> | 4,650       | 286           | 6.2         | 65.0       | 214.6        | 3.3                         |
| LTBC           | 4,650       | 80            | 1.7         | 64.8       | 58.8         | 0.9                         |
| LT             | 4,650       | 44            | 0.9         | 34.5       | 35.5         | 1.0                         |
| Total          | 13,950      | 410           | 2.9         | 164.3      | 308.9        | 1.9                         |
| Lake 97        |             |               |             |            |              |                             |
| F <sub>1</sub> | 6,900       | 346           | 5.0         | 96.5       | 240.7        | 2.5                         |
| LTBC           | 6,900       | 183           | 2.7         | 96.1       | 124.7        | 1.3                         |
| LT             | 6,900       | 1             | 0.0         | 51.2       | 0.4          | 0.0                         |
| Total          | 20,700      | 540           | 2.6         | 243.9      | 366.0        | 1.5                         |
| BT TYPE LAKES: |             |               |             |            |              |                             |
| Pleasant Lake  |             |               |             |            |              |                             |
| F <sub>1</sub> | 2,700       | 170           | 6.3         | 37.8       | 118.3        | 3.1                         |
| BTBC           | 2,700       | 55            | 2.0         | 91.1       | 25.2         | 0.3                         |
| BT             | 2,700       | 54            | 2.0         | 92.4       | 21.2         | 0.2                         |
| Total          | 8,100       | 279           | 3.4         | 221.3      | 164.6        | 0.7                         |
| Lake 78        |             |               |             |            |              |                             |
| F <sub>1</sub> | 6,000       | 356           | 5.9         | 84.0       | 368.2        | 4.4                         |
| BTBC           | 6,000       | 99            | 1.7         | 202.4      | 58.3         | 0.3                         |
| BT             | 6,000       | 88            | 1.5         | 205.4      | 37.2         | 0.2                         |
| Total          | 18,000      | 543           | 3.0         | 491.8      | 463.7        | 0.9                         |

Table 5. Stomach contents, in percentage by incidence, of trout recovered from the matched planting experiments.

| Food Item                                                                                          | Lake Trout Type Lakes |                      | Brook Trout Type Lakes |                      |
|----------------------------------------------------------------------------------------------------|-----------------------|----------------------|------------------------|----------------------|
|                                                                                                    | Bobowash <sup>a</sup> | Lake 97 <sup>a</sup> | Pleasant               | Lake 78 <sup>a</sup> |
| Empty                                                                                              | 42                    | 51                   | 44                     | 38                   |
| Crayfish                                                                                           | 32                    | 1                    | 24                     | 31                   |
| Insects                                                                                            | 17                    | 46                   | 7                      | 8                    |
| Lake herring<br>( <i>Coregonus artedii</i> )                                                       | --                    | --                   | 9                      | --                   |
| White suckers<br>( <i>Catostomus commersoni</i> )                                                  | <1                    | 0                    | 0                      | 2                    |
| Minnows<br>(Cyprinids)                                                                             | 1                     | <1                   | 13                     | 16                   |
| Miscellaneous<br>(unidentified remains,<br>leeches, earthworms,<br>plankton, frogs, fish<br>spawn) | 7                     | 1                    | 3                      | 5                    |

<sup>a</sup> These lakes are not known to contain lake herring.

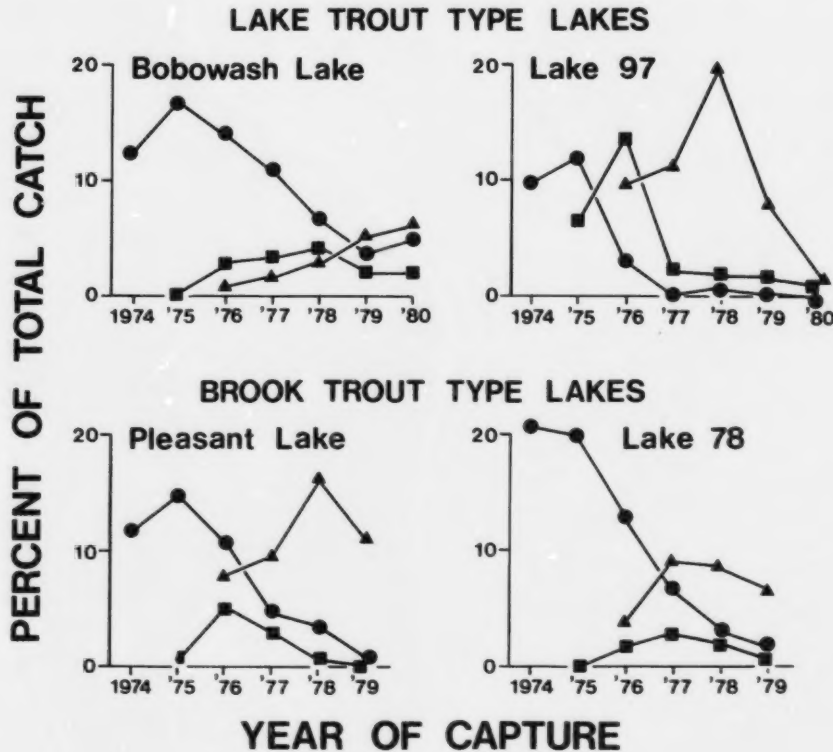


Figure 2. The relative returns from the three plantings (●1974, ■1975, ▲1976) in terms of the percentage of the total number of fish recovered from each lake.

The fish from Lakes 97 and 78 grew faster and attained larger ultimate sizes than those from Pleasant or Bobowash Lakes. These growth differences correspond to the differences in returns from these two sets of lakes, with Lakes 97 and 78 giving better returns than Lakes Bobowash and Pleasant (Fig. 1). The sizes of the backcrosses and BT decreased at age 4-6, as they disappeared from the catch (Fig. 3).

No obvious relationship between the growth rates and stomach contents was observed. The fastest growing fish, from Lakes 97 and 78, had insects and crayfish, respectively, as the food item most frequently observed in their stomachs (Table 5). The slower growing fish of Pleasant Lake had more varied stomach contents, including herring and minnows, in addition to crayfish. The Bobowash Lake fish, which were also slow growing, had crayfish as the most common food item in their stomachs.

The trout from the three successive plantings grew at different rates within each lake. The data are insufficient for meaningful statistical tests, but trends are apparent (Table 6). The growth rates are correlated with the relative recovery rates from the successive plantings. For all four lakes, except perhaps Lake 97, the fish from the second planting, which were recovered in much lower numbers than the fish from the first planting, grew more slowly than the fish from the first planting (Table 6). In Lake 97,

the fish from the second planting gave somewhat better recoveries, and also grew somewhat faster (Table 6).

The lakes that had the poorest recoveries for the third planting (Lakes Bobowash and Pleasant), also had the poorest relative growth for that planting (Table 6); whereas the lake that had the best returns from this planting (Lake 97; Fig. 2) also had the best growth rate.

The relationships noted among lakes, successive plantings, type of cross, growth rates, and recoveries, were also reflected in the condition factors of the fish. The condition factor,  $K$ , was defined according to Carlander (1969) as  $K = (WT/FL^3) \times 10^5$ , where  $WT$ , the weight, is in g and  $FL$ , the fork length, in mm. BT had the highest condition factors with BTBC,  $F_1$ , LTBC, and LT following, in that order (Table 7). This relationship has been described previously (Berst et al. 1980).

The  $F_1$ 's from Lakes 97 and 78, which had the fastest growth rates, also had the highest mean  $K$ 's among the four lakes (Table 7). This relationship also applies to the backcrosses within the two types of lakes. The LTBC's from Lake 97, which had a faster growth rate than those from Lake Bobowash, also had a larger mean  $K$ . This was also the case for the BTBC's from Pleasant Lake and Lake 78. Further, the fastest growing BT (from Lake 78) had larger

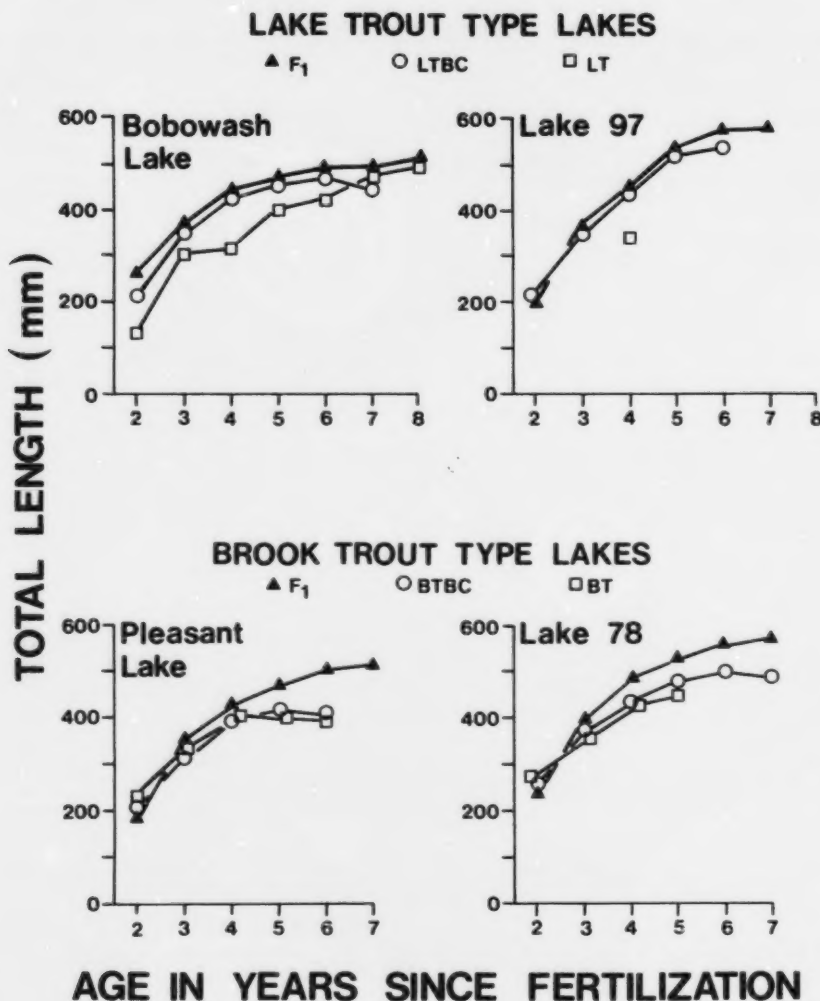


Figure 3. Mean total length versus age, in years, since fertilization for each experimental lake and each cross.

K's than the slower growing BT (from Pleasant Lake). There was insufficient data to compare the LT from Lake 97 and Bobowash Lake.

The relative recovery rates among lakes, both in terms of number and weight, are also correlated with the K factors. Lakes 78 and 97, which had the highest rates of return (Table 3), had the largest K factors for  $F_1$ 's (Table 6); and Pleasant Lake, which had the poorest return, had the lowest mean K for  $F_1$ 's.

The relative performance of successive plantings is also reflected in the K factors. The second planting, which had the poorest returns and growth rates for all four lakes, also had the lowest K factors for  $F_1$ 's and both types of backcrosses for all four lakes, except BTBC in Lake 78. A comparison of the K factors for BT and LT among plantings within lakes was not possible because so few of these fish were recovered from the second planting. In Pleasant Lake, contrary

to the general trend, the BT from the second planting had a larger mean K than the BT from the first planting. The mean K for the second planting, however, was based on only 9 fish. The mean K's for the third planting were generally slightly higher than those for the second planting, but still considerably lower than those for the first planting.

No consistent relationships between age and condition factors were observed (data not shown). The  $F_1$ 's tended to have fairly constant K's over ages. This is contrary to the findings of Fraser (1980) who found increasing K factors with age for  $F_1$ 's in his study lakes. A trend towards slightly higher K factors with age was observed for LTBC's, and a reverse trend for BTBC's and BT. There was insufficient data to comment on any possible relationship between K factor and age for LT.

Table 6. Comparison of growth among the successive plantings for the F<sub>1</sub> hybrids, expressed as mean total length (in mm)<sup>a</sup>. Numbers in brackets represent the number of fish sampled.

| Plantings      | Age in years since fertilization |            |            |            |            |            |           |           |
|----------------|----------------------------------|------------|------------|------------|------------|------------|-----------|-----------|
|                | 1.5<br>(at planting)             | 2          | 3          | 4          | 5          | 6          | 7         | 8         |
| LT Type Lakes: |                                  |            |            |            |            |            |           |           |
| Bobowash L.    |                                  |            |            |            |            |            |           |           |
| 1974           | 104.1                            | 282.3 (49) | 380.8 (57) | 443.8 (51) | 481.3 (36) | 491.4 (16) | 499.0 (6) | 524.1 (7) |
| 1975           | 127.0                            | 183.0 (1)  | 354.0 (4)  | 445.0 (5)  | 432.8 (6)  | 474.3 (3)  | 494.0 (3) | -         |
| 1976           | 115.0                            | 161.3 (3)  | 326.5 (4)  | 426.8 (10) | 455.0 (14) | 511.3 (14) | -         | -         |
| Lake 97        |                                  |            |            |            |            |            |           |           |
| 1974           | 104.1                            | 208.0 (51) | 371.8 (61) | 441.4 (14) | (0)        | (0)        | (0)       | (0)       |
| 1975           | 127.0                            | 226.9 (8)  | 382.7 (13) | 432.2 (5)  | 500.3 (3)  | 557.5 (2)  | 585.0 (1) | -         |
| 1976           | 115.0                            | 211.9 (36) | 374.4 (46) | 468.3 (75) | 544.0 (30) | 579.5 (2)  | -         | -         |
| BT Type Lakes: |                                  |            |            |            |            |            |           |           |
| Pleasant L.    |                                  |            |            |            |            |            |           |           |
| 1974           | 104.1                            | 185.0 (13) | 377.2 (22) | 455.1 (19) | 477.5 (6)  | 514.9 (8)  | 515.5 (2) | -         |
| 1975           | 127.0                            | (0)        | 364.6 (7)  | 390.7 (6)  | 488.0 (1)  | 466.1 (1)  | -         | -         |
| 1976           | 115.0                            | 198.3 (8)  | 322.4 (14) | 416.4 (36) | 475.6 (27) | -          | -         | -         |
| Lake 78        |                                  |            |            |            |            |            |           |           |
| 1974           | 104.1                            | 250.7 (30) | 408.6 (66) | 487.7 (59) | 519.7 (29) | 570.9 (13) | 579.0 (7) | -         |
| 1975           | 127.0                            | (0)        | 397.8 (5)  | 461.2 (11) | 518.4 (10) | 541.0 (3)  | -         | -         |
| 1976           | 115.0                            | 202.0 (6)  | 393.4 (43) | 481.4 (44) | 538.1 (32) | -          | -         | -         |

<sup>a</sup> - means that the lake was not sampled; (0) means that the lake was sampled but no fish were recovered.

Table 7. Condition factor (K) for trout from matched planting experiments.

| Trout          | Year of Planting       |                        |                        | Total             |
|----------------|------------------------|------------------------|------------------------|-------------------|
|                | 1974                   | 1975                   | 1976                   |                   |
| LT Type Lakes: |                        |                        |                        |                   |
| Bobowash L.    |                        |                        |                        |                   |
| F <sub>1</sub> | 1.15±0.01 <sup>a</sup> | 1.09±0.02              | 1.10±0.02              | 1.14±0.01         |
| LTBC           | 1.17±0.02              | 1.08±0.03              | 1.08±0.04              | 1.12±0.01         |
| LT             | 0.99±0.02              | 1.21±0.02 <sup>b</sup> | 1.03±0.03 <sup>b</sup> | 1.01±0.02         |
| Lake 97        |                        |                        |                        |                   |
| F <sub>1</sub> | 1.31±0.02              | 1.18±0.03              | 1.19±0.01              | 1.23±0.01         |
| LTBC           | 1.24±0.04              | 1.18±0.01              | 1.20±0.02              | 1.89±0.01         |
| LT             |                        |                        | 1.13 <sup>c</sup>      | 1.13 <sup>c</sup> |
| BT Type Lakes: |                        |                        |                        |                   |
| Pleasant L.    |                        |                        |                        |                   |
| F <sub>1</sub> | 1.20±0.02              | 1.06±0.02              | 1.09±0.01              | 1.14±0.01         |
| BTBC           | 1.14±0.02              | 1.08±0.02 <sup>b</sup> | 1.13±0.02              | 1.13±0.02         |
| BT             | 1.23±0.03              | 1.31±0.05              | 1.25±0.03              | 1.25±0.02         |
| Lake 78        |                        |                        |                        |                   |
| F <sub>1</sub> | 1.24±0.01              | 1.15±0.02              | 1.17±0.01              | 1.21±0.01         |
| BTBC           | 1.30±0.02              | 1.30±0.03              | 1.20±0.04              | 1.29±0.01         |
| BT             | 1.42±0.02              | 1.33 <sup>c</sup>      | 1.19±0.04              | 1.39±0.02         |

<sup>a</sup> standard error of mean; <sup>b</sup> mean based on only two fish; <sup>c</sup> condition factor for one fish recovered.

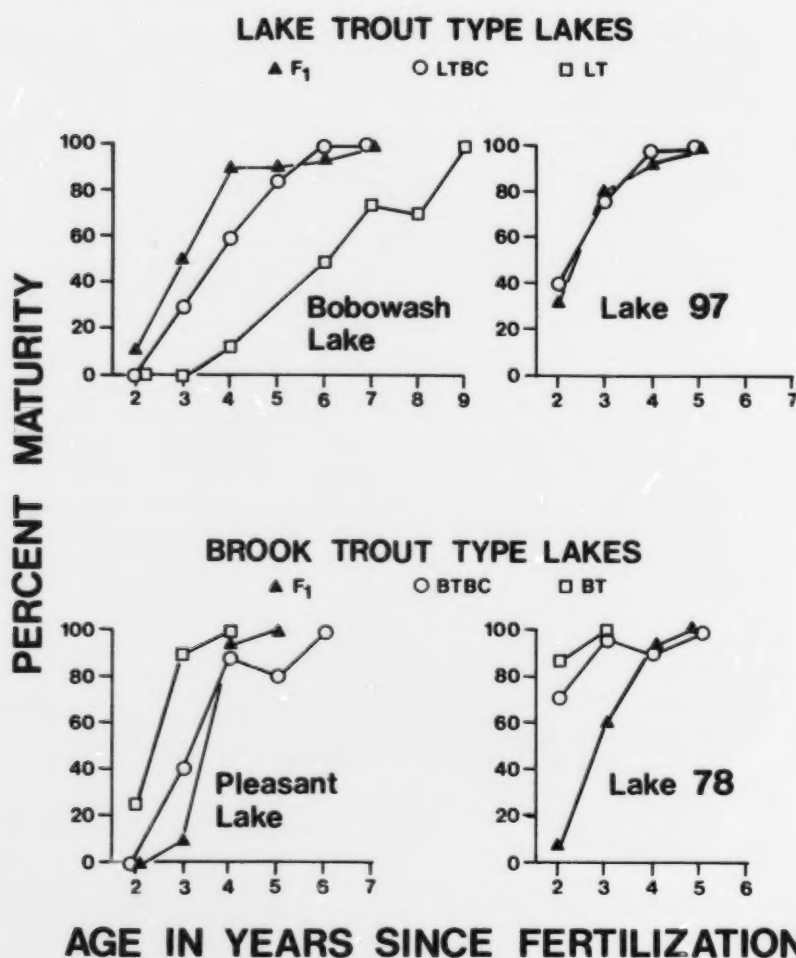


Figure 4. Rate of maturation (sexes combined) for each cross and each lake of the matched planting experiment. Bobowash Lake includes the lake trout from the 1973 planting.

#### MATURATION

The state of maturity of each sample could be determined easily, since the fish were collected during the fall spawning season. As has been reported previously (Berst et al. 1980), F<sub>1</sub> splake hybrids were intermediate in age of maturity to the brook and lake trout parent species (Fig. 4). BTBC were intermediate to the F<sub>1</sub>'s and brook trout; and LTBC were similar to F<sub>1</sub>'s in one lake (Lake 97), somewhat slower maturing than F<sub>1</sub>'s in the other (Bobowash Lake), but faster than LT.

For the BT type lakes, the fish from Lake 78, with faster growth and better survival, matured earlier (Fig. 4). For example, at age three, only about 10% of the F<sub>1</sub>'s from Pleasant Lake were mature, as compared to 60% from Lake 78 (sexes combined). A similar relationship between age of maturity and growth rate and survival was noted for the LT type lakes, with Lake 97 giving faster growth and earlier maturation than Bobowash Lake (Fig. 4).

#### DISCUSSION

The results for all four study lakes show that the F<sub>1</sub> splake are much superior to the backcrosses, and even more so to brook trout and lake trout, in terms of survival and growth. The returns, in terms of numbers and weight, were several fold higher for the F<sub>1</sub> hybrids than the other crosses. The superior performance of the F<sub>1</sub> hybrid is attributed, at least in part, to hybrid vigor, as discussed by Berst et al. (1980). Fraser (1972, 1980) also observed better returns of F<sub>1</sub> splake over brook trout, from small Precambrian Shield lakes, in terms of weight and survival. F<sub>1</sub> splake are also superior in terms of growth (Berst et al. 1980) and survival (Ihssen, unpublished data) to BT, LT, BTBC, and LTBC, under hatchery conditions. Berst and Spangler (1970) reported faster growth for F<sub>1</sub> splake hybrids than for lake trout, in Lake Huron. The growth rate and age of maturity of LT, LTBC, and F<sub>1</sub> splake in Lake Huron has been compared (Spangler and Berst 1976). The F<sub>1</sub> hybrid

was found to be superior in growth to LT, but the LTBC and  $F_1$  hybrids had similar growth rates. In this study, the growth of the  $F_1$  hybrid was found to be somewhat superior to the LTBC. The two studies give similar results for the ages of maturity of these crosses, with  $F_1$ 's maturing first (50% mature at about age 3, about one year earlier for the fast growing Lake 97 population), LTBC about one year later, and LT at about age 6-7. The relative ages of maturity among these crosses are similar under hatchery conditions, with  $F_1$ 's and LT maturing about one year earlier than in the wild ( $F_1$ , age 2; LTBC, age 3-4; LT, age 5) (Berst et al. 1980).

A number of  $F_1$ 's (88) were recovered as 6-8 year olds of trophy size (1.5-2.2 kg), whereas the oldest brook trout recovered was one 6 year old (0.8 kg). This is similar to Fraser's (1972) finding that  $F_1$ 's survived to trophy size, but brook trout did not. BTBC were similar to BT, in that only a few fish (5) six years old and older were recovered. The poor survival of the BT and BTBC may be, in part, a domestication effect. These two crosses were derived from domestic females, and Fraser (1981) has shown that BT from domesticated stock females were recovered at a rate of only one-half to one-quarter the rate of BT derived from wild females.

LT and LTBC performed somewhat better, relative to  $F_1$ 's, than BT and BTBC, with respect to long-term survival. Very few young LT were recovered (6 fish, age 2-4), whereas an increasing number were recovered for the older age classes (9 fish, 6 years old; 10 fish, 7 years old; 13 fish, 8 years old). Most of the LTBC's were recovered as 3-4 year olds, but a significant number appeared as 6-8 year olds (30). Since lake trout grow more slowly than the other crosses, especially during their first few years after planting, they may not have been as vulnerable to the gill nets as the other crosses, for these early sampling years, even though mesh sizes down to 20 mm were used. Nevertheless, there is little doubt that the LT did not survive as well as the  $F_1$ 's or LTBC's, since relatively few were recovered, even when they reached a size at which they were expected to be as vulnerable to the gill-netting as the  $F_1$ 's or LTBC's.

The poor performance of the middle plant in all four lakes, in terms of survival and growth, suggests competition among the plantings. The middle plant only contributed about 15% to the total catch, even though it was equal in size to the first and third plant.<sup>1</sup> The somewhat reduced catch from the third plant, relative to the first plant, also is attributed to competition, primarily from the survivors of the first plant, since the fish from the second plant were not very abundant. The theory that competition among plantings

affected survival is also supported by the negative correlation between the returns from the first and third plant (Fig.2).

If competition among the plantings is a major factor in determining the survival of the planted trout, the comparative survival of the individual crosses might be affected differentially by different levels of abundance of the three plantings. The percentage of each type of cross recovered from the two types of lakes, for each of the three plantings, is given below. (The number of fish recovered is in brackets.)

| Trout         | Planting      |               |               |
|---------------|---------------|---------------|---------------|
|               | 1st<br>(1974) | 2nd<br>(1975) | 3rd<br>(1976) |
| LT Type Lakes |               |               |               |
| $F_1$         | 82 (343)      | 27 (54)       | 73 (235)      |
| LTBC          | 10 (42)       | 70 (139)      | 25 (82)       |
| LT            | 8 (34)        | 3 (5)         | 2 (6)         |
| BT Type Lakes |               |               |               |
| $F_1$         | 56 (273)      | 71 (44)       | 76 (209)      |
| BTBC          | 23 (110)      | 13 (8)        | 13 (36)       |
| BT            | 21 (102)      | 16 (10)       | 11 (30)       |

For the LT lakes, it is seen that LTBC's contributed a much larger proportion to the catch from the second plant than the first or third plant. The relative recoveries of  $F_1$ 's and LTBC's from the third plant are similar to the first plant, with a slight shift towards LTBC. One interpretation of this result is that there is greater competition among similar genotypes than among dissimilar genotypes, as represented by the different crosses. Since the different crosses have different temperature preferences and depth distributions (Berst et al. 1980) during critical times of the year, they may be segregating and competing more among themselves than with other crosses. Intra-cross competition would explain the relatively better performance of the LTBC's over the  $F_1$ 's of the second plant. Under this assumption, the high abundance of the  $F_1$ 's and low abundance of the LTBC's would result in a lower abundance of  $F_1$ 's and a higher abundance of LTBC's from the second plant, as was observed. The reduced returns of the LTBC's from the third plant would then be explained by competition from the more abundant LTBC's from the second plant. Similarly, the better performance of the  $F_1$ 's from the third plant would be explained by the lower abundance of the  $F_1$ 's from the second plant. For the BT type lakes, a similar trend is observed for the  $F_1$ 's, but not as marked for the BTBC's, probably because of their much lower overall abundance than the LTBC's, after the first planting.

Competition among fish of the same cross for successive plantings is of interest to the management of these small lakes, for example, for  $F_1$  put-delay-take fisheries. The results from this study strongly indicate that plantings

<sup>1</sup> For this calculation, the returns of the second and third planting were adjusted to correct for the fact that they were only sampled in six and five seasons, respectively, as compared to seven seasons for the first planting.

of  $F_1$ 's in successive years should only be employed if each planting is heavily exploited, the year immediately after planting. Otherwise, the second planting will only contribute marginally to the fishery. For lakes that are not heavily exploited, these results suggest that planting of  $F_1$ 's in alternate years would be sufficient, with only a small effect of competition resulting between plants separated by two years.

The matched planting experiment was designed to compare the performance of different genotypes, as represented by the different hybrids and parental species, under the same environmental conditions. Extrapolating these results to single species or hybrid plantings must be made cautiously, because of possible environmental-genetic interaction and competition effects. Nevertheless, since the  $F_1$  hybrid consistently out-performed the other hybrids and the parent species by a large margin, in different lakes, the environmental-genetic interaction effects on these differences in performance are likely to be small, compared to the heterotic advantage of the  $F_1$  hybrid. Therefore, comparative single species or hybrid performance in different lakes is expected to be similar to that observed in the matched planting experiment. This is borne out by the work of Martin and Baldwin (1960) on BT, LT and  $F_1$  hybrids, and that of Fraser (1980) on BT and  $F_1$  hybrids. They also found, for single species or hybrid plantings, that the  $F_1$ 's were superior in growth (Martin and Baldwin 1960) and survival (Fraser 1980) to the parent species.

The correlation observed in this study among growth rate, condition factor, and abundance suggests an indirect method of assessing whether a planting will perform well in terms of survival. It is much easier to estimate the mean condition factor (K) of a stock than its abundance. Therefore, since the condition factor and abundance are correlated, the success of a planting can be indirectly assessed from the condition factor. It is suggested that the condition factor is particularly useful for comparing the relative performance of successive plantings in the same lake. But even among lakes in this study, those that gave the poorest returns (Lakes Bobowash and Pleasant) gave the lowest K values (Pleasant Lake,  $K = 1.14$ ; Bobowash Lake,  $K = 1.14$ ; Lake 78,  $K = 1.21$ ; Lake 97,  $K = 1.23$ ). Within lakes, the poorer returns of  $F_1$ 's from the second planting were always associated with a significant reduction in the K factor, as summarized below. The improved performance of the third plant also is associated with a slight recovery of the K factor.

|             | First<br>Planting | Second<br>Planting | Third<br>Planting |
|-------------|-------------------|--------------------|-------------------|
| Lake 97     | $1.31 \pm 0.02$   | $1.18 \pm 0.03$    | $1.19 \pm 0.01$   |
| Lake 78     | $1.24 \pm 0.01$   | $1.14 \pm 0.02$    | $1.17 \pm 0.01$   |
| Bobowash L. | $1.15 \pm 0.01$   | $1.09 \pm 0.02$    | $1.10 \pm 0.02$   |
| Pleasant L. | $1.20 \pm 0.02$   | $1.06 \pm 0.02$    | $1.09 \pm 0.01$   |

Therefore, it is suggested that the condition factor for the first plant be compared with subsequent plants. If a reduction in the range of 0.06-0.14 occurs, it is a strong indication that the plant is not very successful. Only about 30 fish from each plant need to be weighed and measured (not necessarily killed) to make this determination. Because of seasonal variation, it is suggested that the comparison be made among fish sampled at the same time of the year. For species such as brook trout, which have a sexual dimorphism for the K factor (Berst et al. 1980), equal numbers of each sex should be compared.

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